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# EPA/AEERL (Environmental Protection Agency/Air and Energy Engineering Research Laboratory) Source Testing Program for Coal Gasification Technologies (Kosovo TestSite)

Radian Corp., Austin, TX

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# EPA/AEERL SOURCE TESTING PROGRAM FOR COAL GASIFICATION TECHNOLOGIES (Kosovo Test Site)

by

Karl J. Bombaugh
Radian Corporation
Austin, TX 78766

William J. Rhodes
Air and Energy Engineering Research Laboratory
U.S. Environmental Protection Agency
Research Triangle Park, NC 27711

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EPA Project Officer
William J. Rhodes

AIR AND ENERGY ENGINEERING RESEARCH LABORATORY
OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
RESEARCH TRIANGLE PARK, NC 27711

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16. ABSTRACT

The paper summarizes EPA's environmental assessment testing program for synthetic fuels technology, with emphasis on the Kosovo source test and evaluation program. The Kosovo program included: (a) field tests to characterize process waste streams that would be input to control technologies in U.S. synfuels plants, (b) characterization of fugitive emissions, and (c) characterization of components in the ambient air and correlation of those components with source characterization data. Results from the Kosovo program have been (and are being) used: (a) to evaluate and select pollution control technologies for U.S. coal gasification plants using pressurized fixed-bed gasification technology, (b) as input to health studies, (c) to develop worker health and safety programs for U.S. synfuels plants, (d) to acquire environmental permits which address regulated and nonregulated pollutants, (e) to develop supplemental environmental monitoring plans required by the U.S. Synthetic Fuels Corporation, and (f) to develop and validate ambient air monitoring methodology.

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# EPA/AEERL SOURCE TESTING PROGRAM FOR COAL GASIFICATION TECHNOLOGIES
(Kosovo Test Site)

Karl J. Bombaugh
Radian Corporation
8501 MoPac Boulevard
Austin, TX 78766

William J. Rhodes
U. S. Environmental Protection Agency
Air and Energy Engineering Research Laboratory
Research Triangle Park, N.C. 27711

This paper summarizes the past EPA/AEERL (formerly IERL-RTP) environmental assessment testing program for synthetic fuels technology, with particular emphasis on the Kosovo source test and evaluation program. The Kosovo program contained three distinct elements: (a) field testing to characterize process waste streams that would be input to control technologies in U.S. synfuels plants, (b) characterization of fugitive emissions, and (c) characterization of components in the ambient air and correlation of those components with source characterization data.

Results from the Kosovo program have been and are being used (a) to evaluate and select pollution control technologies for U.S. coal gasification plants using pressurized fixed-bed gasification technology, (b) as input to health studies, (c) to develop worker health and safety programs for U.S. synfuels plants, (d) to acquire environmental permits which address regulated and nonregulated pollutants, (e) to develop supplemental environmental monitoring plans required by the U. S. Synthetic Fuels Corporation, and (f) to develop and validate ambient air monitoring methodology.

This paper summarizes the Kosovo program results. Examples of how those results have been used to select pollution controls, develop worker health and safety programs, acquire permits, and prepare supplemental environmental monitoring plans are discussed. Also, other source test and evaluation programs supported by EPA/AEERL are briefly summarized.

During the past 10 years, EPA/AEERL has conducted source test and evaluation programs at commercial-, pilot-, and bench-scale coal gasification facilities. The objectives of these programs were to provide test data for:

- characterization of regulated and nonregulated species in process waste streams;
- evaluation of pollution control process performance;
- development of sampling and analytical methods for characterizing constituents in process waste streams;
- evaluation of the potential health and ecological effects of process waste streams;
- development of pollution control schemes for treating gaseous, liquid, and solid waste streams;
- providing input to federal, state, and local regulatory agencies; and
- providing input to health studies.

Table 1 lists the source test and evaluation programs conducted by EPA/AEERL. One of the most comprehensive source tests was performed at Kosovo's gasification plant in Southern Yugoslavia. As a result, this paper summarizes the environmental study at the Kosovo complex. Examples of how the Kosovo results have and can be used are also given.

The Kosovo program included four elements:

- a source characterization,
- a fugitive emissions study,
- an ambient air study, and
- a health effects study.

The first three elements have been completed, and the fourth is in progress. Results of the completed elements have been documented (1-21) and are included in the EPA data base that was established within the framework of the previously defined objectives.

TABLE 1. SOURCE TEST AND EVALUATION PROGRAM

| Plant | Gasification Process |
|---|---|
| Duluth (University of Minnesota) | Foster Wheeler/STOIC (low-Btu) fixed-bed |
| Ft. Snelling | Wellman-Galusha (low-Btu) fixed-bed |
| Glen Gery | Wellman-Galusha (low-Btu) fixed-bed |
| Holston | Wilputte/Chapman (low-Btu) fixed-bed |
| Kosovo | Lurgi-type, fixed-bed |
| Worcester | Riley Gas Producer (low-Btu) fixed-bed |
| Modderfontein | Koppers-Totzek entrained-bed |
| Ruhrkohle/Ruhrchemie | Texaco entrained-bed |
| Waltz Mills | KRW fluidized-bed |

This presentation addresses the completed elements; emphasis is on the results of the source characterization and on the contribution of the source to the plant's ambient air.

## DESCRIPTION OF THE TEST SITE

The Kosovo gasification plant is part of a large mine-mouth industrial complex, near the city of Pristina, in the Kosovo Region of Southern Yugoslavia. The complex consists of a coal mine, a coal preparation plant, the gasification plant, a steam and power generation plant, an ammonia plant, and an air separation plant.

The industrial complex is in a broad valley about 80 km long, 15 km across, and 1 km deep. The valley floor is divided into smaller pockets by lesser hills. The complex is surrounded by farm land that is interspersed with small villages. The climate in the valley is comparable to that in midwestern USA.

The gasification plant (Figure 1) consumes dried coal (lignite) and produces two primary products: hydrogen for use in ammonia synthesis and a medium-Btu fuel gas. Several by-products are also produced: tar, medium oil, naphtha, and crude phenol.

Run-of-mine coal from the Kosovo mine is dried by the Fleissner process and sized to select particles ranging in diameter from 6 mm to 60 mm. The coal is then fed to pressurized fixed-bed gasifiers (Lurgi-type) where it is reacted with oxygen and steam at 2.5 MPa (25 atm) pressure. The crude product gas is cooled, cleaned, and piped to the utilization site.

As the crude product is quenched and cooled, tars, oils, and naphtha are condensed and removed in a phenolic water stream. Acid gases ($H_2S$ and $CO_2$) are removed from the product gas by sorption with cold methanol.

The acid-gas-rich methanol is regenerated, releasing a waste gas rich in $H_2S$, which is flared, and a $CO_2$-rich waste gas which is vented to the atmosphere. Tars and oils are removed from the phenolic water stream by decantation, after which the water soluble organics (crude phenols) are recovered by extraction with diisopropyl ether. Four liquid by-products (tar, medium oil, naphtha, and crude phenol) are collected and held in storage tanks for further use. Ammonia, removed from the phenolic water by steam-stripping, is vented to the atmosphere.

Gasifier ash and a sediment from the water/oil decantation process (heavy tar) are dispersed in a nearby landfill along with ash from the coal combustion processes.

## TEST RATIONALE

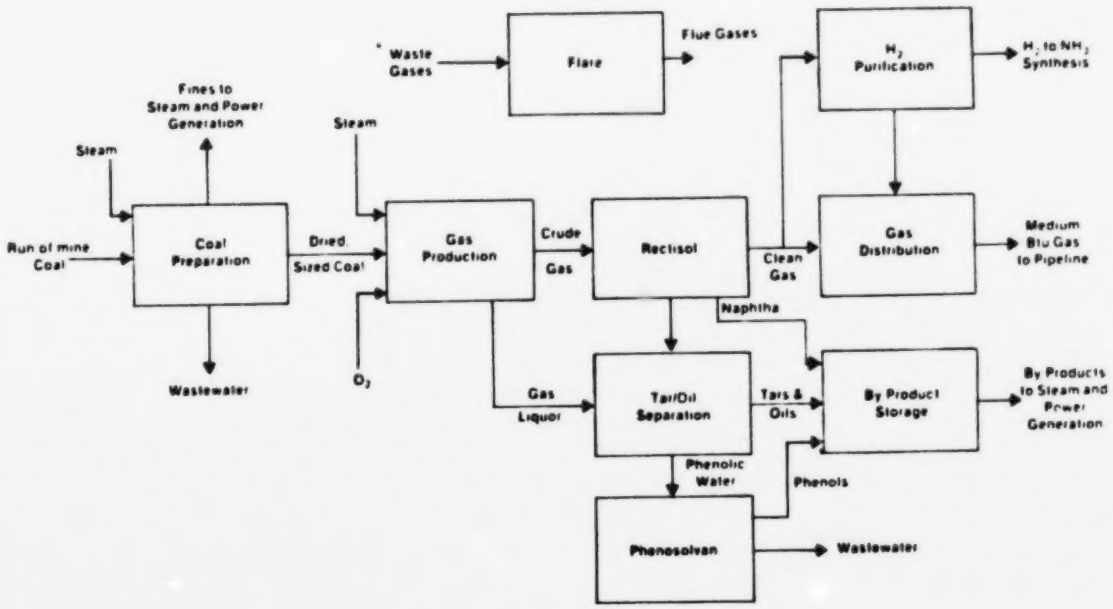
Gaseous, liquid, and solid waste discharges from the respective process units were examined to identify and measure stream pollutants. The discharge streams may be classified as:

- those discharged to another operating unit or
- those discharged to the environment.

Although all discharges were important to understanding the potential environmental problems associated with coal gasification and gas cleaning, this division into categories was useful in establishing a "source-receptor" relationship in the air study at Kosovo.

Since the plant uses no modern emission control devices, the data describing emissions measured and the pollutants found pertain only to that source-receptor and cannot be applied unilaterally to other situations. However, these results have provided and can continue to provide valuable guidance to both the environmental science and the synfuel technology communities particularly because the results represent a real-life situation that has been in operation for several years.

For the extensive data obtained from the Kosovo facility to be properly interpreted, it must be recognized that the Kosovo plant does not include all of the design and operating features




* Combined waste gas from several sources.

Figure 1. Simplified schematic of the Kosovo coal gasification plant.

of modern Lurgi-type facilities. For example, the Kosovo plant does not employ many of the pollution control processes which will be incorporated in U. S. gasification facilities. Therefore, many of the "uncontrolled" discharges from the Kosovo plant are not representative of the "controlled" discharges from Lurgi-type facilities that will be built in the U. S. However, the process and "uncontrolled" discharge streams of Kosovo are expected to be similar in composition and relative flow rate to analogous internal streams in future U. S. plants with similar design features. Within these constraints, the data obtained in this study provide a valuable data base for evaluating and selecting pollution control units, developing permit applications, and assessing potential health effects.

## EXPERIMENTAL TEST DESCRIPTION

The source characterization, completed in several phases, consisted of a screening study during which about 50 streams were sampled and analyzed for major and minor pollutants, after which 20 to 30 streams were sampled and analyzed by more detailed procedures for major, minor, and trace pollutants.

The fugitive emission study was an effort to determine the actual fraction and rate-fraction of potential leak sources for the plant. The four major objectives of this assessment were: 1) determination of the frequency of leak occurrence, 2) measurement of leak rates from leaking sources, 3) estimation of total fugitive emissions from leakage, and 4) comparison of the results to other fugitive emissions from test data. Included were valves, pumps, flanges, and open-ended lines. The test consisted of actually locating and counting all flanges, valves, and couplings in the plant, then selecting a statistical sample, screening with a portable hydrocarbon detor, and ultimately enclosing detected sources for an accurate leak rate measurement.

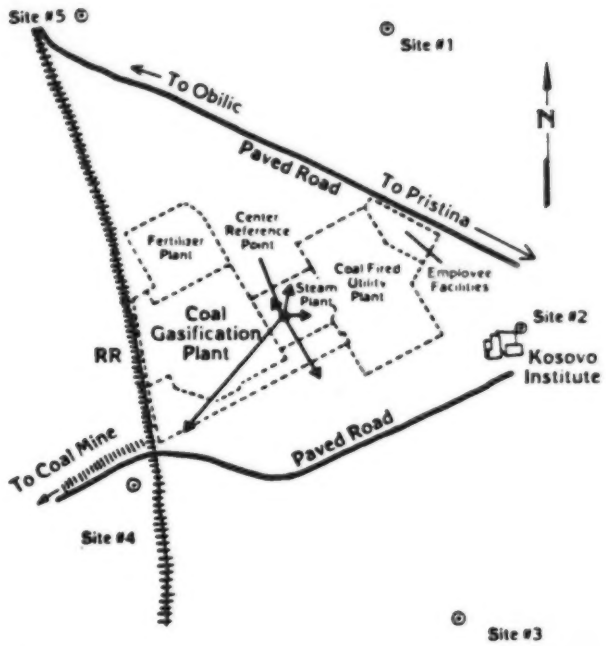
In the ambient air study, five monitoring stations were set up on a perimeter, 1 to 2 km from the virtual center of the complex (the steam plant stack, Figure 2) to collect particulates and organic vapors. Two stations contained meteorological equipment to record air temperature, wind velocity (direction and speed), and relative humidity. Collections were measured and analyzed for both organic and inorganic components. Source/receptor relationships were evaluated using both mass balance (17) and fingerprint concepts (4, 9, 15).

The investigation involved EPA/AEERL, EPA/ESRL-RTP, a prime contractor, nine subcontractors, and funding support from DOE for the fugitive emissions study.

## RESULTS AND DISCUSSION

The source test produced more data than practical for a single presentation. The following list illustrates the volume of data obtained from the source characterization:

- Concentrations of individual species in the following categories: fixed gases, major sulfur species, $C_2$-$C_6$ non-aromatic hydrocarbons, light aromatics, and major nitrogenous species in 14 gaseous discharge streams.
- Condensible organics - determined as volatile and nonvolatile organics in 21 streams.
- Particulate concentrations in six gaseous streams.
- Polynuclear aromatic measurements for six hazardous species, including benzo(a)pyrene, in nine gas streams and two organic liquid streams.
- Thirty-three water pollutant determinations and 54 trace element concentrations in 3 aqueous streams.
- Twenty-two determinations for physical properties and chemical compositions and trace element determinations (54 by SSMS, 14 by AA) in four solid waste streams.
- Flow rate measurements in all streams with each sampling.




Note: Vectors indicate the relative amount of time that each receptor site was downwind.

Figure 2. Schematic of the Kosovo industrial complex.

These results alone provide several thousand data points representing about 100 different species or parameters on up to 35 individual streams. In addition, the data from the five monitoring stations used in the ambient air study produced thousands of additional data points, so that there is no convenient way to provide a comprehensive summary of the overall results of the program. Instead only highlights of the results shall be given in this summary.

## Source Testing

The major gaseous discharge streams, in terms of pollutant concentration and mass flow, are listed in Table 2. The mass discharge rates from these major streams are shown in Figure 3, in which the species, determined individually, are grouped into classes. The top figure shows the plant-wide discharge rates (i.e., to the atmosphere and to the flare) of seven major gaseous pollutants; the center figure shows the mass discharge rates of those pollutants to the atmosphere; and the bottom figure shows the mass discharge rates of those pollutants to the flare. Since the rate scale is logarithmic, each unit represents a 10X increase in rate: scale magnitudes cannot be added to obtain a summation of rates.

Concentrations ranged from the percent level for major components such as CO, to tenths of a percent for minor components such as non-methane hydrocarbons or light aromatics, and to parts per million for PNAs. Concentration levels of these component classes in the discharge from the LP coal lock vent, a significant stream that is discharged to the atmosphere at Kosovo, are shown in Figure 4. Concentration units are expressed in micrograms per cubic meter; here a log scale is used so that each unit represents a 10X increase.

Particulate discharges from the Kosovo plant, collected by wet impingers, were measured as three fractions:

- o filterable solids,
- o dissolved solids, and
- o tars/oils (condensed organics).

Table 3 shows the mass concentrations of the particulates being discharged to the atmosphere and to the flare. The particulates in all process streams contain a significant portion of organics:

| Stream/Fate | Wt% of Particulates In Tar/Oil Fraction |
|---|---|
| LP Coal Lock Vent/To atmosphere | 90 |
| Gasifier Start-up Vent/To atmosphere | 95 |
| HP Coal Lock Vent/To flare | 69 |
| Tar Separation Waste Gases/To flare | 72 |
| Combined Gases to Flare/To flare | 76 |

The composition of these organics is similar to that of two process by-products, tar and medium oil, which are similar in composition to the organics transported in the process discharge streams. Condensibles collected in an impinger train, using a combination of low temperature condensation and sorption on Tenax* resin, showed that these streams carried relatively large amounts of organics. Volatile and nonvolatile organics (Table 4) were determined by the EPA Level 1 protocol for Total Chromatographable Organics (TCO) and Gravimetrically Determined Organics (Grav), respectively. Light aromatics were determined separately as a summation of toluene, xylene, and phenol.

Although some of these values are not entirely consistent, they provide a reasonable indication of the levels of organics in these discharges, as well as the relative distributions of high-to-low molecular weight compounds. These organics are composed of aromatic and heterocyclic compounds containing S, N, and O as well as combinations of the heteroatoms.

The concentrations of four polynuclear aromatics -- benzo(a)anthracene (BaA), benzo(a)pyrene (BaP), dibenzo(a,h)anthracene (dBahA), and benzo-(h)fluoranthene (BhF)--in nine discharge streams are shown in Table 5. Highest concentrations were found in the LP coal lock vent which, at a concentration of 670 $\mu g/m^3$, was discharging 14,000 µg of BaP per gasifier per hour.

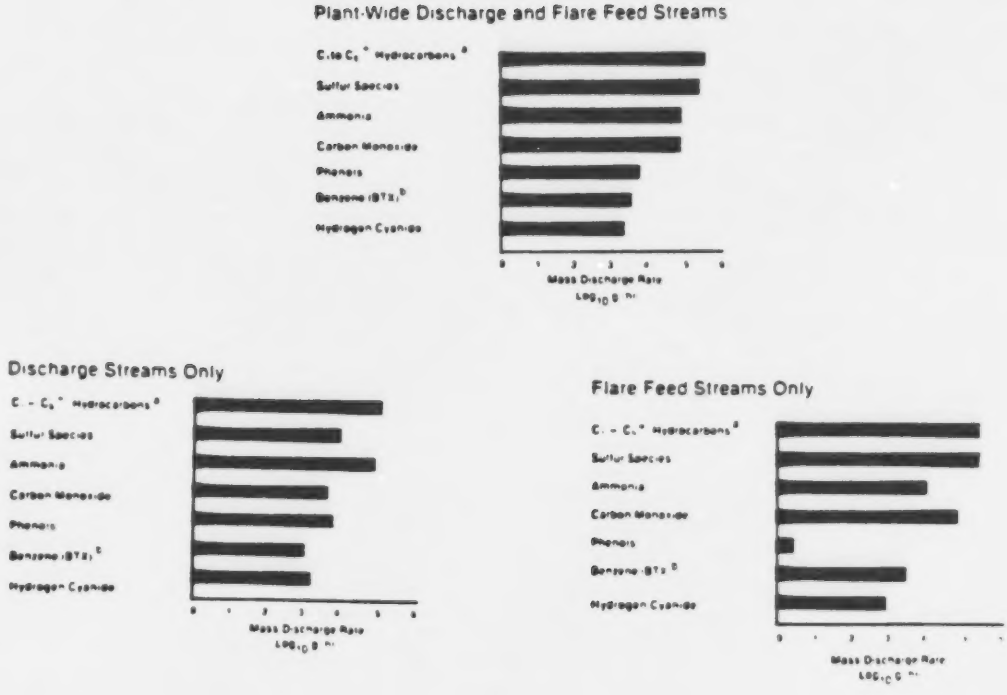
* Registered trademark of Rohm and Haas

TABLE 2. MAJOR KOSOVO DISCHARGE STREAMS BASED ON POLLUTANT CONCENTRATION AND MASS FLOW RATE (5)

| | Highest Concentration | | Greatest Mass Flow Rate | |
|---|---|---|---|---|
| Pollutant | Direct Atmospheric Discharges | Total Plant[a] | Direct Atmospheric Discharges | Total Plant[a] |
| CO | LP Coal Lock Vent | LP Coal Lock Vent | LP Coal Lock Vent | $H_2S$-Rich Waste Gas |
| $C_1$-$C_6$ | Naphtha Storage Tank Vent | Naphtha Storage Tank Vent | $CO_2$-Rich Waste Gas Vent | $H_2S$-Rich Waste Gas |
| BTX[b] | Naphtha Storage Tank Vent | Naphtha Storage Tank Vent | Phenolic Water Tank Vent | Tar Separation Waste Gas |
| Total Sulfur Species | Medium Oil Tank Vent<br>Naphtha Storage Tank Vent<br>Phenolic Water Tank Vent | $H_2S$-Rich Waste Gas | Ammonia Stripper Vent | $H_2S$-Rich Waste Gas |
| $H_2S$ | Medium Oil Tank Vent | $H_2S$-Rich Waste Gas | Ammonia Stripper Vent | $H_2S$-Rich Waste Gas |
| COS | LP Coal Lock Vent | $H_2S$-Rich Waste Gas | $CO_2$-Rich Waste Gas | $H_2S$-Rich Waste Gas |
| Mercaptan | Naphtha Storage Tank Vent | Naphtha Storage Tank Vent | Ammonia Stripper Vent | $H_2S$-Rich Waste Gas |
| Phenols | Ammonia Stripper Vent | Ammonia Stripper Vent | Ammonia Stripper Vent | Ammonia Stripper Vent |
| $NH_3$ | Ammonia Stripper Vent | Ammonia Stripper Vent | Ammonia Stripper Vent | Ammonia Stripper Vent |
| HCN | Ammonia Stripper Vent | Ammonia Stripper Vent | Ammonia Stripper Vent | Ammonia Stripper Vent |

a Includes both direct discharge and flare fed streams.

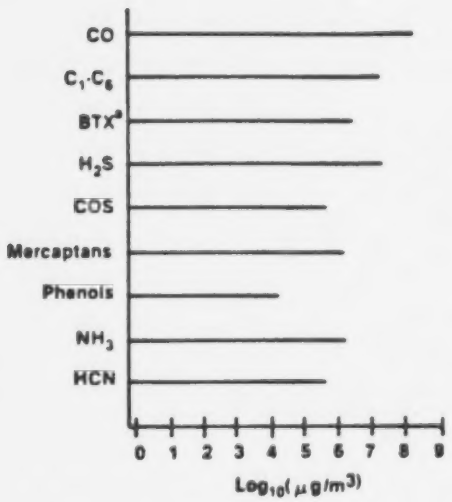
b Benzene, toluene, and xylenes.




[a]Excluding Benzene

[b]BTX = Benzene, toluene, xylenes

Figure 3. Total mass flow rate in Kosovo gaseous streams (5).




[a]BTX=Benzene, toluene, and xylenes.

Figure 4. Mass concentration of potential pollutants in the low pressure coal lock vent discharge stream (5).

TABLE 3. PARTICULATE CONCENTRATION DATA FOR KOSOVO GASEOUS STREAMS (10)

| STREAM TYPE: | DISCHARGE STREAMS | | | FLARE FEED STREAMS | | |
|---|---|---|---|---|---|---|
| SAMPLE POINT: | Coal Room Vent | Low Pressure Coal Lock Vent | Gasifier Start-up Vent | High Pressure Coal Lock Vent | Tar Separation Waste Gas | Combined Gases to Flare |
| Dry Gas Flow Rate ($m^3$/gasifier-hr @ 25°C) | 7200 | 21 | a | 230 | 28 | 1330 |
| Total Particulate (mg/$m^3$ @ 25°C) | 98 | 8100 | 9450 | 960 | 920 | 410 |
| Condensed Organics (Tars and Oils) | b | 7300 | 8980 | 660 | 660 | 310 |
| Dissolved Solids | b | 650 | 400 | 240 | 230 | 54 |
| Filtered Solids | b | 220 | 61 | 61 | 29 | 47 |

[a] Variable flow rate

[b] Dry stream, analysis not applicable

TABLE 4. CONCENTRATIONS OF VOLATILE AND NONVOLATILE ORGANICS IN KOSOVO PLANT GAS STREAM CONDENSATES (10)

| Source | mg/m$^3$ | | | |
|---|---|---|---|---|
| | Light Aromatics[a] | Volatile Organics[b] (TCO) | Total Organics[c] | % Non-volatile Organics[c] |
| Fleissner Autoclave Vent | -[d] | 306 | 1,113 | 73 |
| LP Coal Lock Vent | 1,170 | 3,732 | 7,739 | 52 |
| HP Coal Lock Vent | 1,730 | 1,622 | 2,872 | 43 |
| Start-up Vent | - | 2,670 | 9,820 | 73 |
| $H_2S$-Rich Waste Gas[e] | 30 | 40 | 130 | 69 |
| $CO_2$-Rich Waste Gas | 10 | 5 | 14 | 64 |
| Tar Tank Vent | 3,790 | 10,785 | 14,412 | 25 |
| Medium Oil Tank Vent | 6,060 | 19,921 | 21,118 | 6 |
| Tar Separation Waste Gas | 5,190 | 2,335 | 3,302 | 29 |
| Phenolic Water Tank Vent | 21,670 | 115,012 | 124,881 | 8 |
| Ammonia Stripper Vent | 23,800 | 56,167 | 99,218 | 43 |
| Naphtha Storage Tank Vent | 7,410 | 5,089 | 5,588 | 9 |
| Combined Gas to Flare | - | 312 | 602 | 48 |

[a] These values are a summation of toluene, xylene, and phenol as determined during the Phase II test and are included for comparison to the Volatile Organics column.

[b] Volatile organics were determined as total chromatographable organics (TCOs) using EPA Protocol which is based on a gas chromatographic determination of substances eluting in the range of $C_7$ to $C_{16}$ hydrocarbons representing a boiling range between 100 and 300°C.

[c] Non-volatile organics were determined gravimetrically using EPA's Protocol for "Grav" which includes all substances retained from a 24-hour ambient evaporation. The Protocol may allow the same mid-range volatiles to be included in both determinations; consequently the total may be higher than the true value. The numbers in the Total Organics column are the sum of the TCO and Grav.

[d] Not determined.

[e] No XAD-2 value included.

TABLE 5. CONCENTRATIONS ($\mu g/m^3$) of SELECTED HAZARDOUS POLYNUCLEAR AROMATICS IN KOSOVO GASEOUS DISCHARGE STREAMS (10)

| Source | BaA | BaP | dBahA | BhF |
|---|---|---|---|---|
| LP Coal Lock Vent | 163 | 670 | 52 | 670 |
| Ammonia Stripper Vent | 85 | 20 | <2.1[a] | 12 |
| Naphtha Storage Tank Vent | <0.06 | 0.085 | 0.06 | 0.11 |
| Start-up Vent | -[b] | 139 | <2.1 | - |
| Tar Tank Vent | - | 252 | <10 | - |
| Phenolic Water Tank Vent | - | <50 | <50 | - |
| Medium Oil Tank Vent | - | <6.5 | <6.5 | - |
| $H_2S$-Rich Waste Gas | - | <0.6 | <0.6 | - |
| $CO_2$-Rich Waste Gas | - | <0.7 | <0.7 | - |

[a] All < values calculated from minimum detectable concentration of 0.1 ppm in measuring solution.

[b] Not determined.

## Fugitive Emission Study

The fugitive emission study indicated that the leak factors and leak rates of gases and vapors from valves, flanges, and pump seals at the Kosovo plant are no worse than those from other facilities of comparable age and function (13). The processes utilized at Kosovo may be likened to processes used at petroleum and chemical plants (e.g., gas cleaning, pressurized low temperature fractionation, liquid-liquid extraction) in the U.S.

The results show similarities to those from U.S. oil refineries and organic chemical plants where most individual sources tested have low emission rates, and where most total emissions are contributed by a small fraction of the sources. Based on emission factors developed from the test data, Kosovo fugitives from valves, pumps, and flanges emit 5.7 kg/day of hydrocarbons (based on 30 metric tons per hour coal feed rate). The environmental concern associated with fugitive emissions depends on the composition of the process fluid contained by the source, because the emissions are the result of process fluid leakage from valve packing and seals, pump seals, and flange gaskets. In this regard, there would be some differences in the composition of emissions between coal gasification and the refineries and chemical plants.

Fugitive emission controls that have been implemented in the U. S. oil and chemical industry include leak detection/repair strategies and substitution of equipment components with lower leak potential. These controls also apply to fugitive emission sources in coal gasification plants and should be considered during the design of these plants.

## Ambient Air Study

Aerosol samples, collected from five stations around the plant, indicated a source/receptor relationship. Several methods were used to investigate the relationship:

- o fingerprinting organics (4, 9, 15),
- o upwind/downwind mass balance (17),
- o organic carbon/elemental carbon/carbonate correlations in carbonaceous aerosols (18),
- o trace element distributions (19),
- o scanning electron microscopic examination of particles (20), and
- o anions and cation analysis of particles (20).

Of these, fingerprinting provided the highest correlations. Examples of fingerprinting are shown in Figures 5 and 6. An element-specific detector was used to prepare a gas chromatogram of the organic aerosols suspected to be in the plant's discharge (e.g., medium oil).

The similarity of the two chromatograms in Figure 5 is evident. In this example, a nitrogen-specific detector was used to produce the chromatograms which show a series of alkylthiophenes plus other unidentified species. Similar results (not shown here) were obtained with a sulfur-specific detector which showed an array of alkylthiophenes. The mass balance technique, which relies on a universal detector, also showed that the source was contributing pollutants to the air at the receptor site (i.e., downwind enrichment), but that the existing background of hydrocarbons produced some interferences.

Included in the many organic compounds collected at the receptor site were aromatics such as benzene, naphthalene, and polycyclics, plus their alkyl derivations; phenols and alkyl phenols; and heterocyclics of sulfur, nitrogen, and oxygen.

Table 6 shows the concentration levels of some of the pollutants collected downwind from the plant. The major receptor was downwind from the site 45% of the collecting time so the values shown in Table 6 are computed to 100% downwind.

## SUMMARY

The Kosovo study has provided data describing the raw discharges from a commercial, pressurized, fixed-bed coal gasification process and the effect of that process on its surrounding atmosphere. The data from this study have been used extensively in:

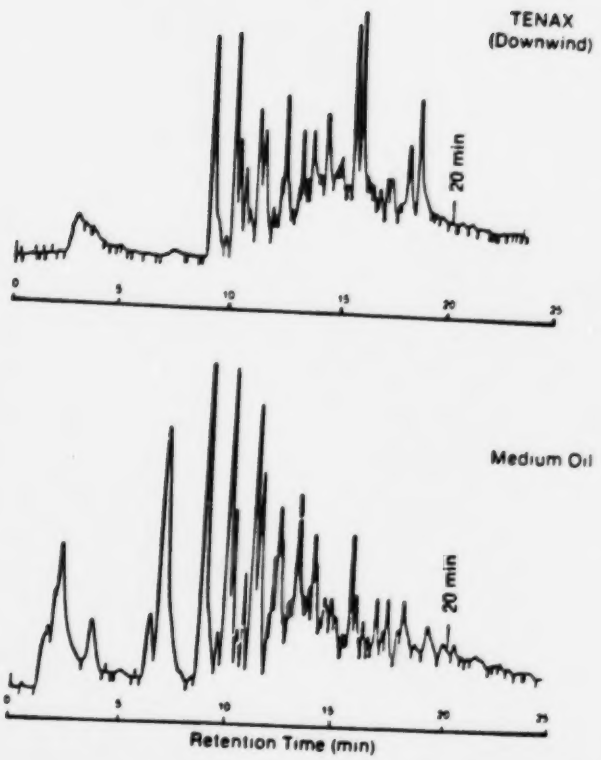



Figure 5. Nitrogen compound profiles for a downwind sample and for Kosovo medium oil (4).

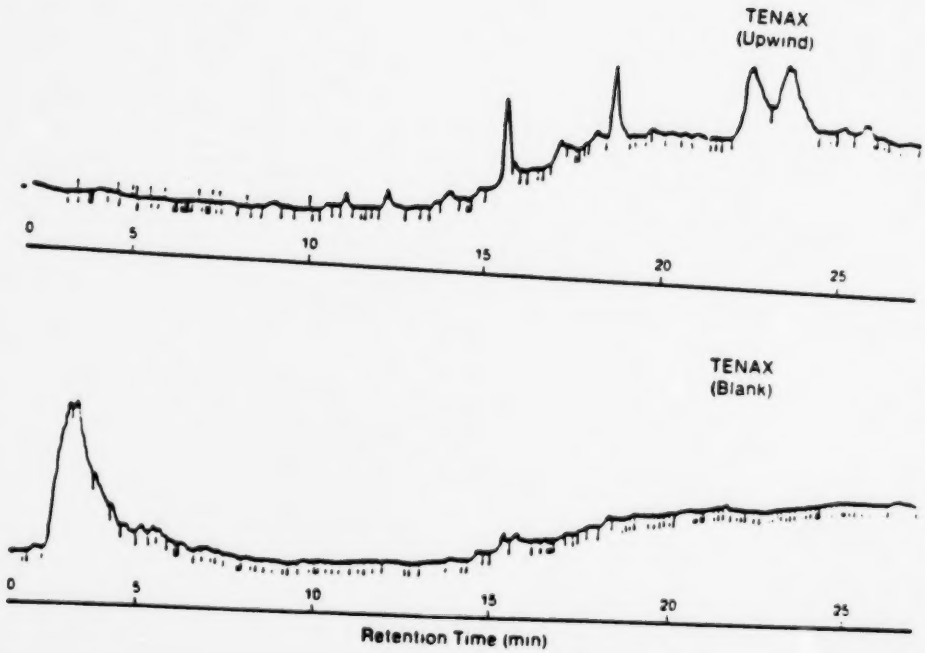



Figure 6. Nitrogen compound profiles for an upwind and a blank sample (4).

TABLE 6. CONCENTRATIONS OF SELECTED POLLUTANTS IN THE AIR DOWNWIND FROM THE KOSOVO COAL GASIFICATION PLANT (4)

| Chemical Species | $\mu g/m^3$ |
|---|---|
| Naphthalene | 7.8 |
| Benzo(a)pyrene | 0.02 |
| Phenol | 6.0 |
| Phenols (phenol + alkyl phenols) | 16.0 |
| Methyl thiophene | 0.30 |
| Pyridine | 0.08 |
| Dibenzofuran | 0.90 |
| Trimethylphenylindan | 0.04 |

- o evaluating and selecting pollution controls for coal gasification plants in the U.S. that use pressurized fixed-bed technology (22, 23),
- o planning and preparing for health studies to be conducted at Kosovo,
- o designing and developing worker health and safety programs for U. S. synfuels plants,
- o preparing permit applications for commercial projects (e.g., trace element results from Kosovo were used to prepare a document for a state agency concerning the rate of lead and mercury discharges),
- o preparing the environmental monitoring plans required by the U. S. Synthetic Fuels Corporation (24), and
- o developing and validating waste stream and ambient air monitoring methods.

Because of its comprehensive scope, data from this study have provided a valuable base for continued investigations. Table 7 lists references to publications that report and utilize Kosovo test results.

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TABLE 7. DOCUMENTATION OF KOSOVO TEST RESULTS

| Subject | Reference Numbers | | |
|---|---|---|---|
| | Final Reports | Symposium Proceedings | Open Literature |
| Discharges | 3, 8 | 1, 2, 5, 7, 10 | 14, 21 |
| Ambient Air | 4 | 6 | 9, 15, 16, 17, 18, 19, 20 |
| Fugitive Emissions | 13 | 12 | -- |
| Control Technology | 22, 23, 24 | 11 | -- |

11. Page, G. C., W. E. Corbett, and R. A. Magee, "Application of Kosovo (Lurgi) Gasification Plant Test Results to Pollution Control Process Design," EPA-600/9-82-017 (NTIS PB83-128181), p. 23, August 1982.

12. Honerkamp, R. L., "Gaseous Fugitive Emissions from Synfuels Production -- Sources and Controls," EPA-600/9-82-017 (NTIS PB83-128181), p. 293, August 1982.

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22. Pollution Control Technical Manual for Lurgi-based Indirect Coal Liquefaction and SNG, EPA-600/8-83-006 (NTIS PB83-214478), April 1983.

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24. Environmental Monitoring Reference Manual for Synthetic Fuels Facilities, EPA-600/8-83-027 (NTIS PB83-251850), July 1983.